Combined Weathering & Corrosion Testing

Applications, Methods, & Limitations

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Topics

- Accelerated tests for product qualification
- History of combined weathering & corrosion testing
- Overview of current methods
- Recent Studies
- Reproducibility challenges

Matrix of Accelerated Tests

Accelerated Test Type	Result	Test Time	Results compared to	Research? Development? Certification?
Quality Control	Pass / fail	• Defined • Short	Material specification	Certification & Research
Qualification / validation	Pass / fail	• Defined • Medium-long	Reference material or specification	Certification & Development
Correlative	Rank-ordered data	• Open-ended • Medium	Natural exposure (Benchmark site)	Development
Predictive	Service life Acceleration factor	• Open-ended • Long	Natural exposure (Service environment)	Development & Warranty Contracts

What happens when your customer's qualification test gives incorrect data?

They still want their warranty!

Protective Coatings
Industrial Maintenance Coatings
Marine Coatings

- Primary job is to protect steel structures, industrial hardware, or other infrastructure in corrosive environments
- Sunlight exposure is often a factor
- Re-coating can be very expensive

Infrastructure Protection

- Bridges
- Metal buildings
- Petrochemical plants

Topics

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- **History of combined weathering & corrosion testing**
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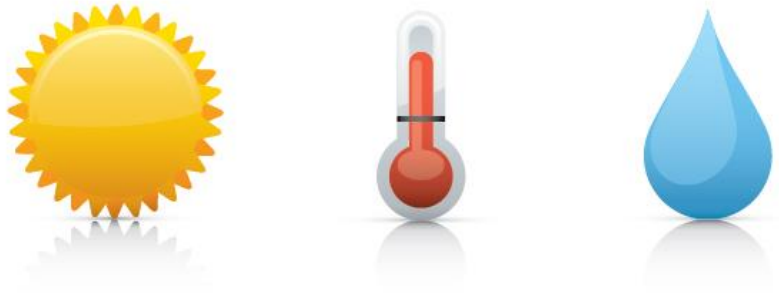
Weathering and Corrosion



Weathering

Changes in material properties resulting from exposure to the radiant energy present in **sunlight** in combination with **heat** (including temperature cycling) and **water** in its various states, predominately as humidity, dew, and rain.

(Atmospheric) Corrosion

Deterioration and destruction of a material and its vital properties due to **electrochemical reactions** on the surface of a metal in an atmospheric environment. It occurs when the surface is **wet by moisture** formed due to rain, fog and condensation.

Combined Corrosion/Weathering

- Developed in the 1980s by Sherwin Williams

Combined Corrosion/Weathering

As a coating degrades from UV exposure, its ability to protect against corrosion is reduced

Combined Weathering/Corrosion Cycle

7 Days

UVA-340	*4:00*	*0.89 W/m²/nm*	*60°C*
Condensation	*4:00*		*50°C*

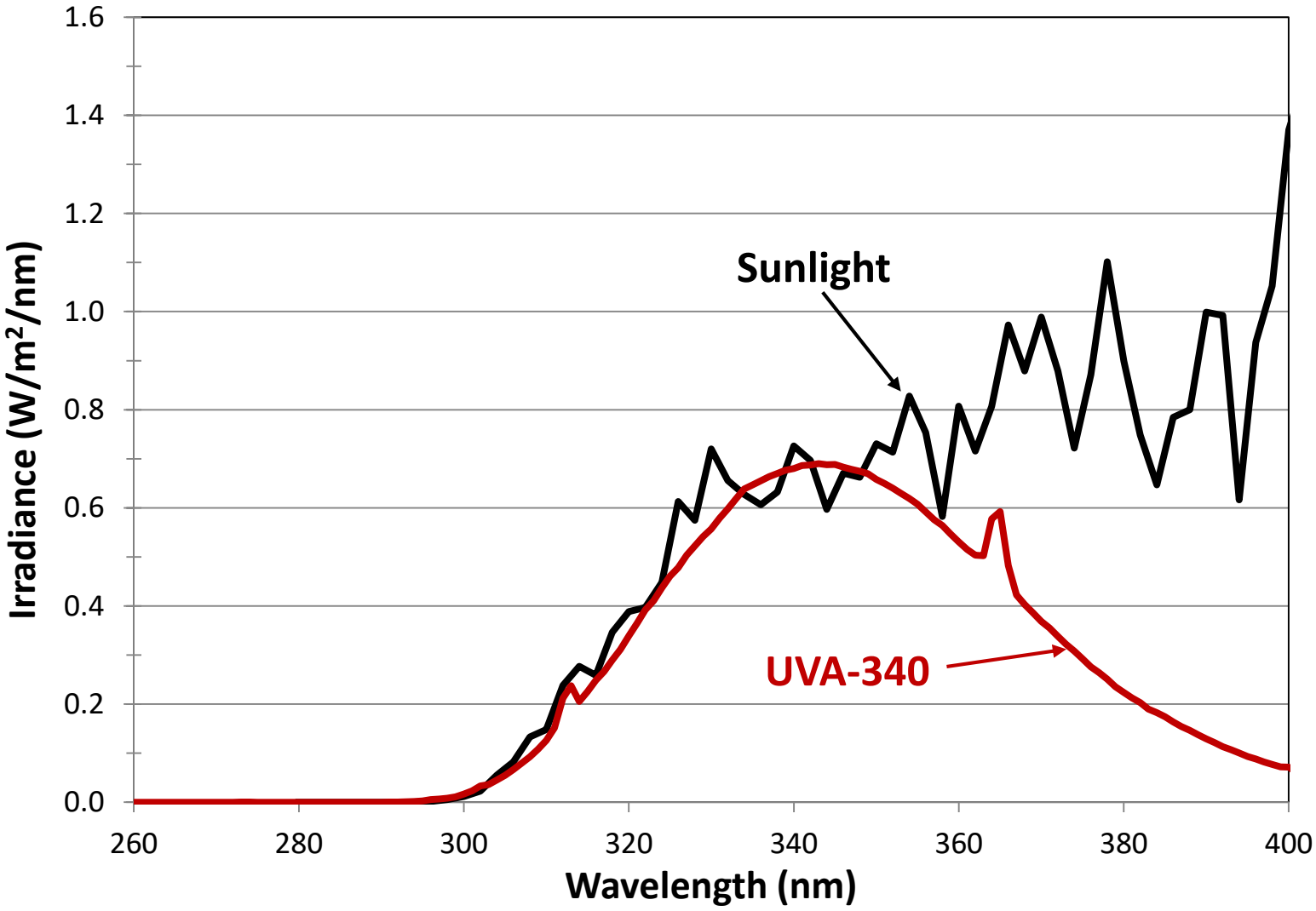
7 Days, ASTM G85 A5

Fog (dilute solution)	*1:00*	*24°C*
Dry-off	*1:00*	*35°C*

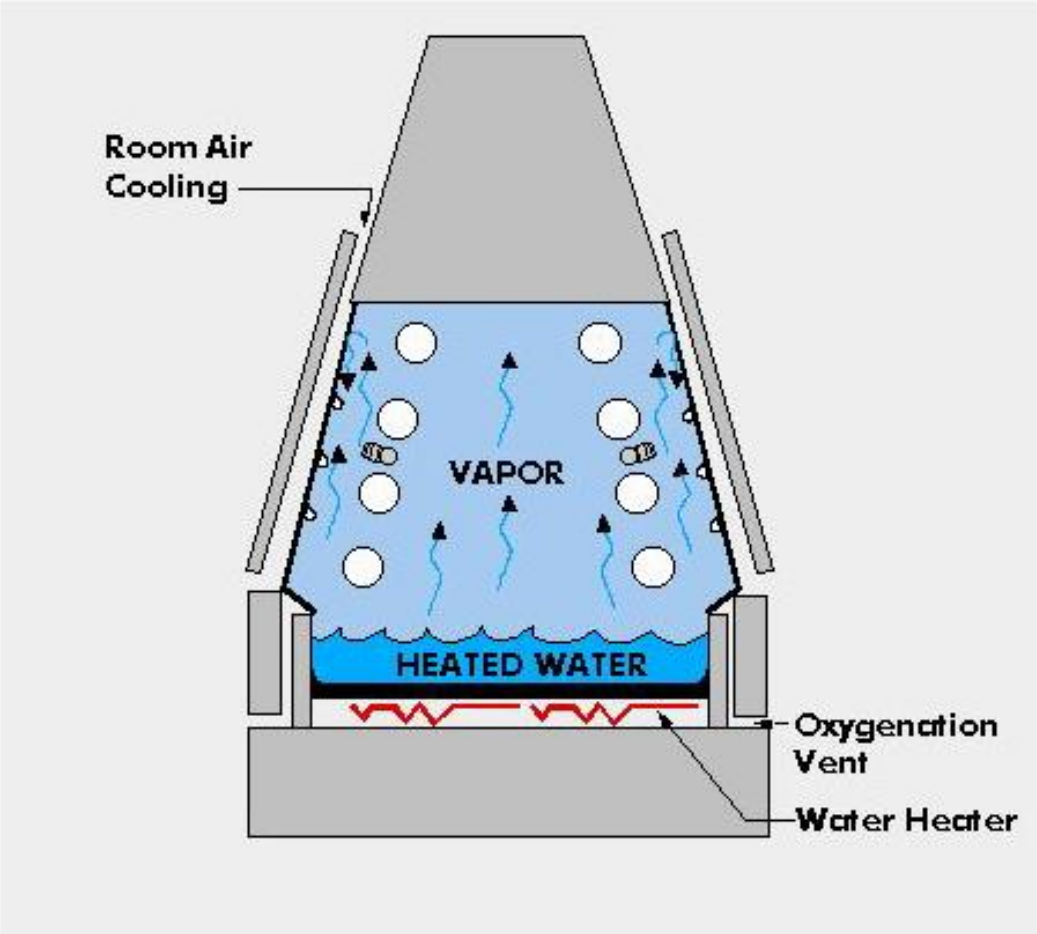
Fluorescent UV Weathering Tester

QUV shown with new dual-touchscreen controller

UVA-340 Lamps

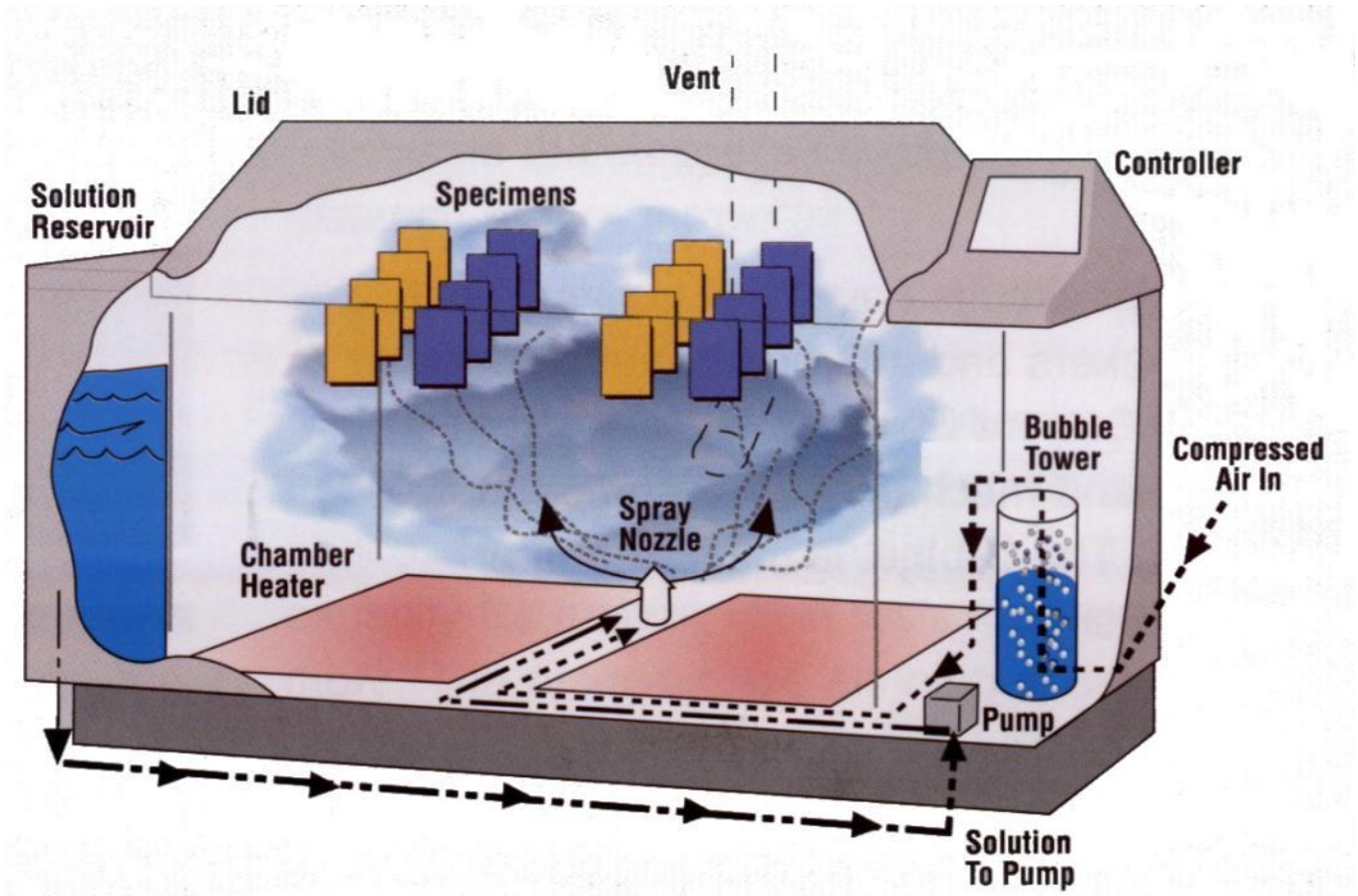


Condensation



Hot condensation is very effective at simulating moisture absorption in a wet environment such as Florida.

Continuous Salt Spray
Salt Fog Environment

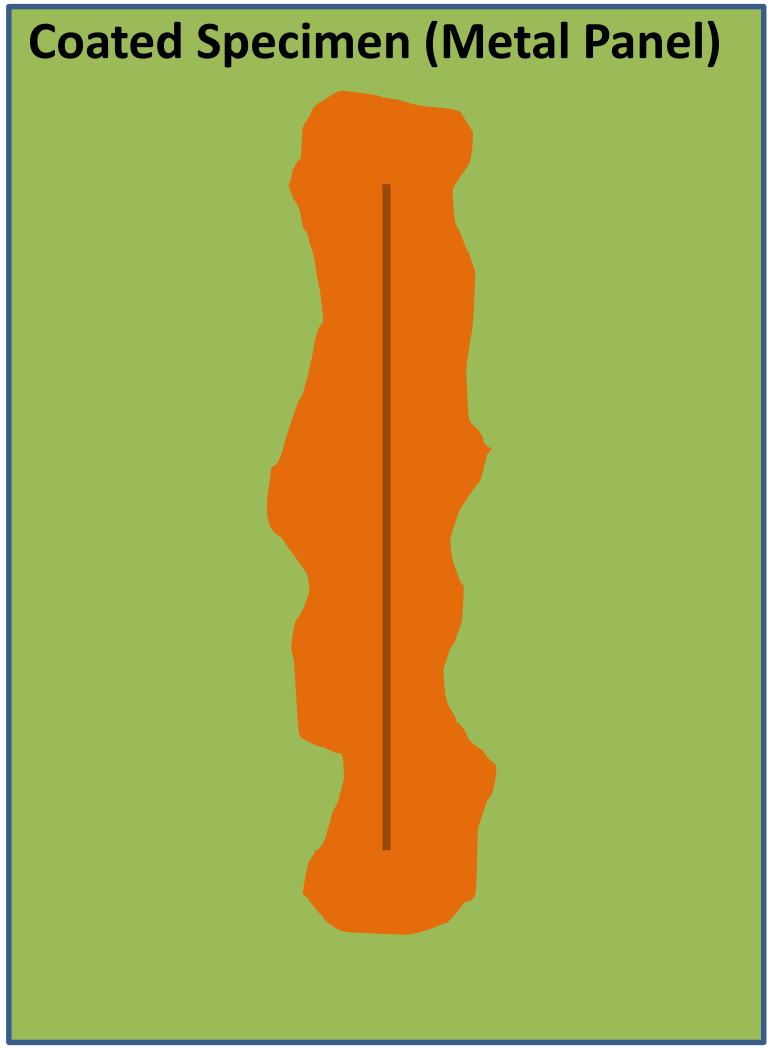


A solution of NaCl or other salts is pumped to an atomizing spray nozzle along with moisturized compressed air, creating a very fine mist that appears similar to fog.

Corrosion Specimen Evaluations

- ***Corrosion creep along a scribe***
- Blistering
- Degree of rusting (ASTM D610)

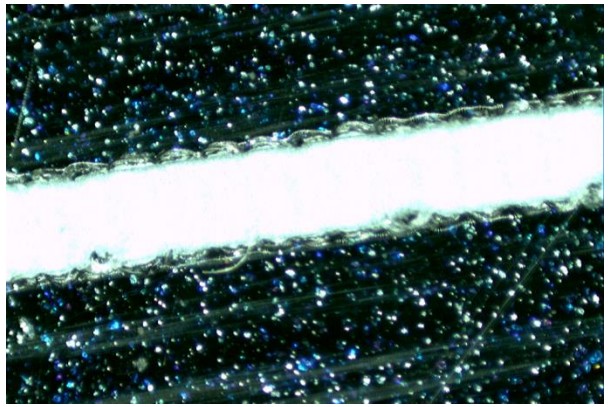
Corrosion Along a Scribe



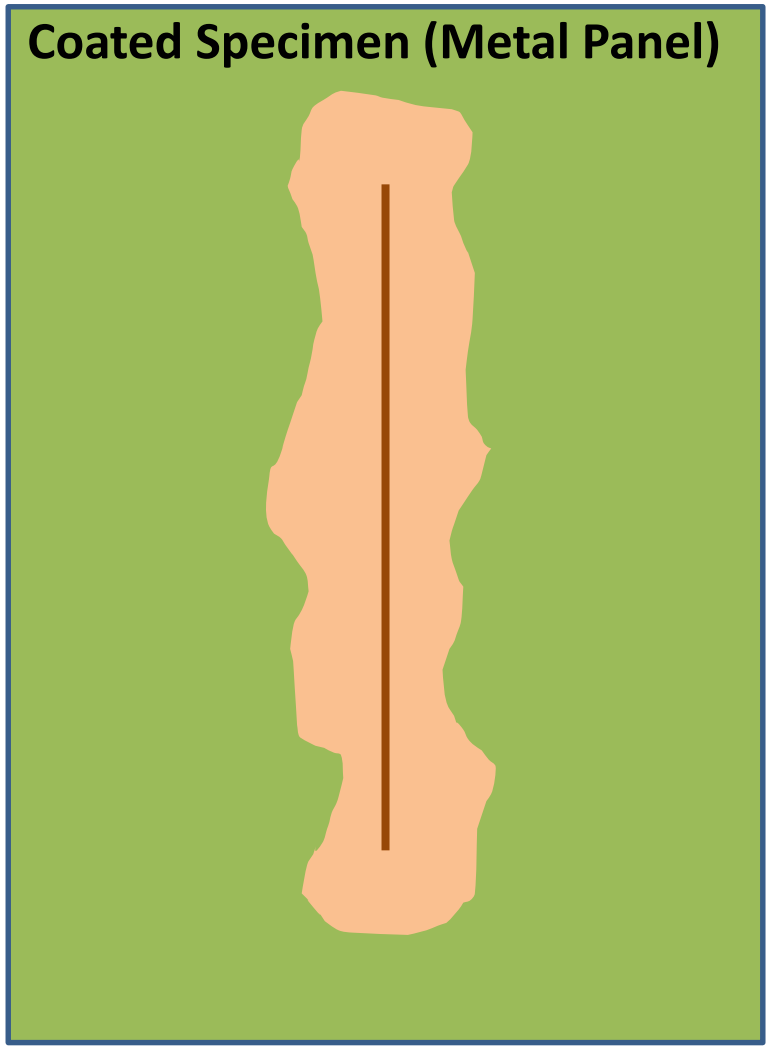
Scribing Tool

Scribe (cut) through the coating to the metal substrate

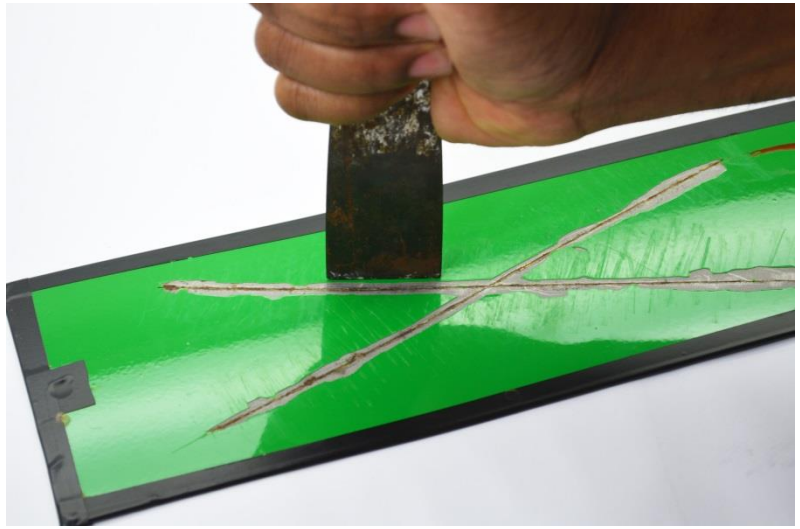
Expose the panel and allow corrosion to “creep” from the scribe



Corrosion Along a Scribe

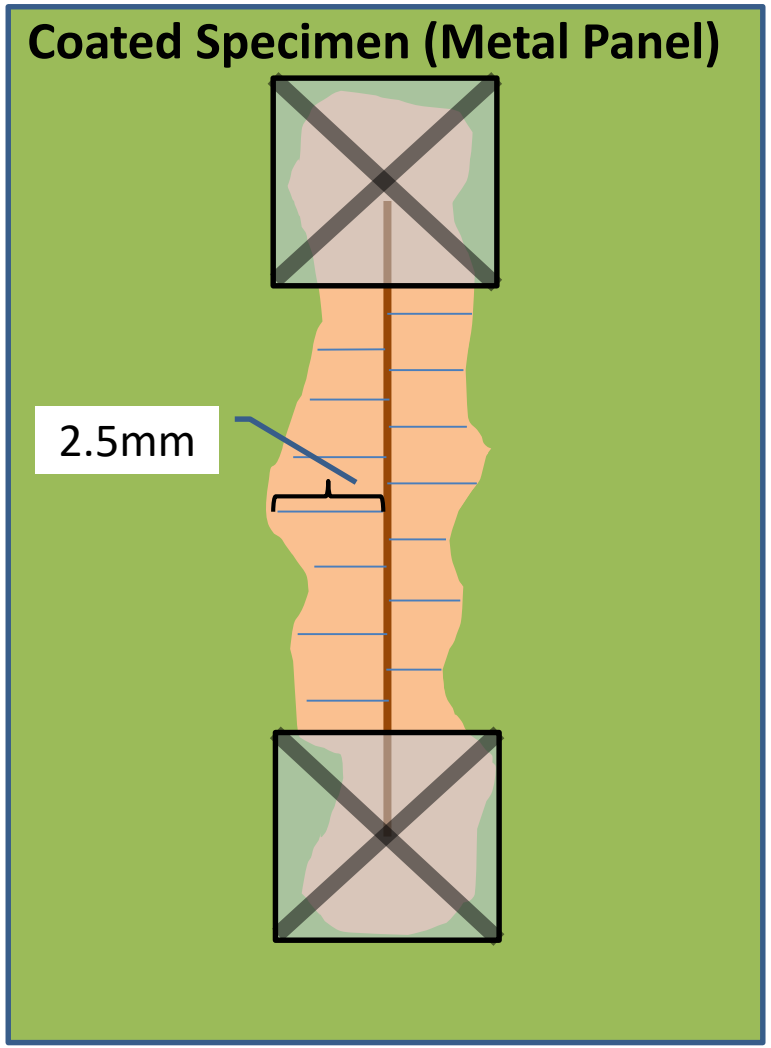


Remove rust “scab” with dull blade



Now the panel is ready for evaluation

Corrosion Along a Scribe



Ignore corrosion areas near ends of scribe (approximately 6-12 mm)

Create grid lines (minimum of 6) from scribe perpendicular to edge of corroded areas— transparency can be placed over panel for this purpose

Measure distance between scribe and edge of corrosion

Paint removed due to loss of adhesion is a separate measurement

Corrosion Specimen Evaluations

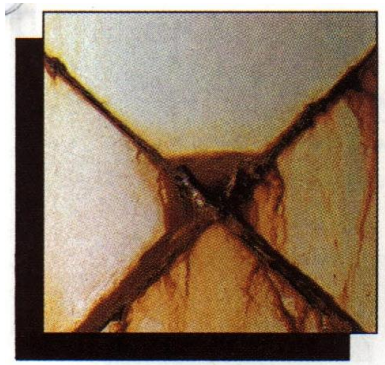
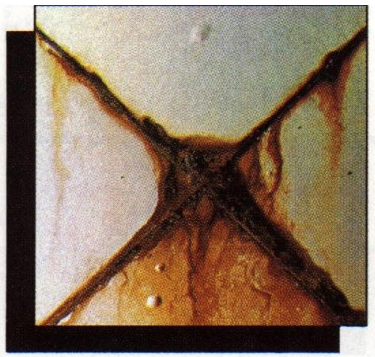
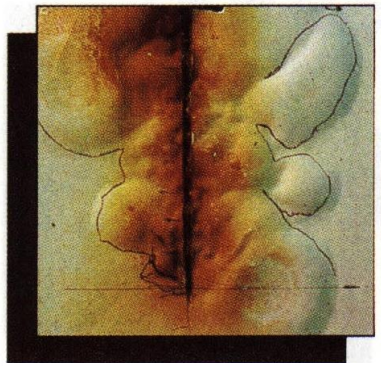
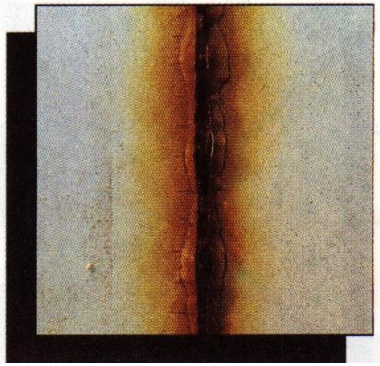
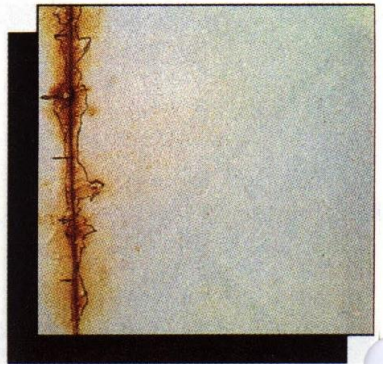
Corrosion creep

Vs

Loss of adhesion (cathodic delamination)

In this study, delamination data from laboratory tests correlated best to outdoor data

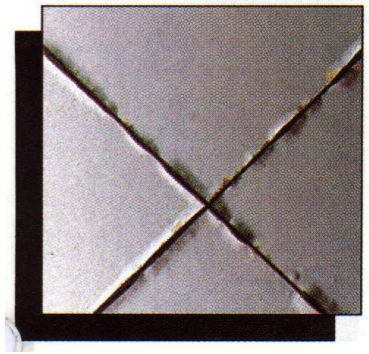
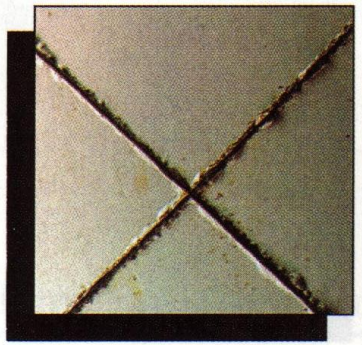
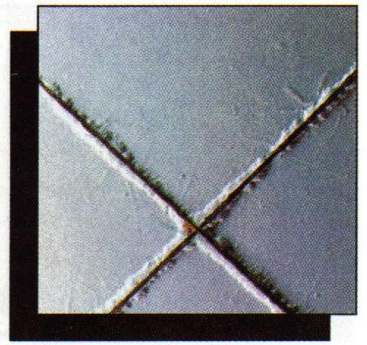
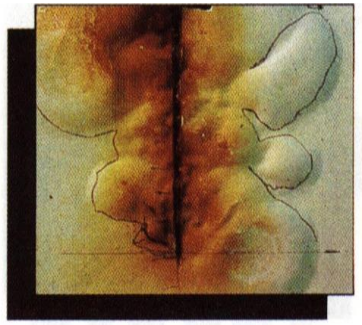
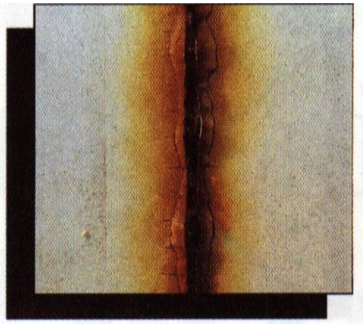
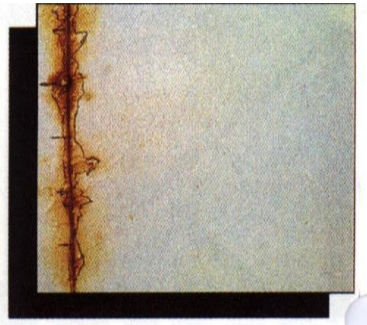
Salt Spray vs Outdoors

	Epoxy	Alkyd	Latex
Salt Spray			
Outdoor			

Salt Spray for 2000 hours (1000 for latex)

27 months outdoor marine environment

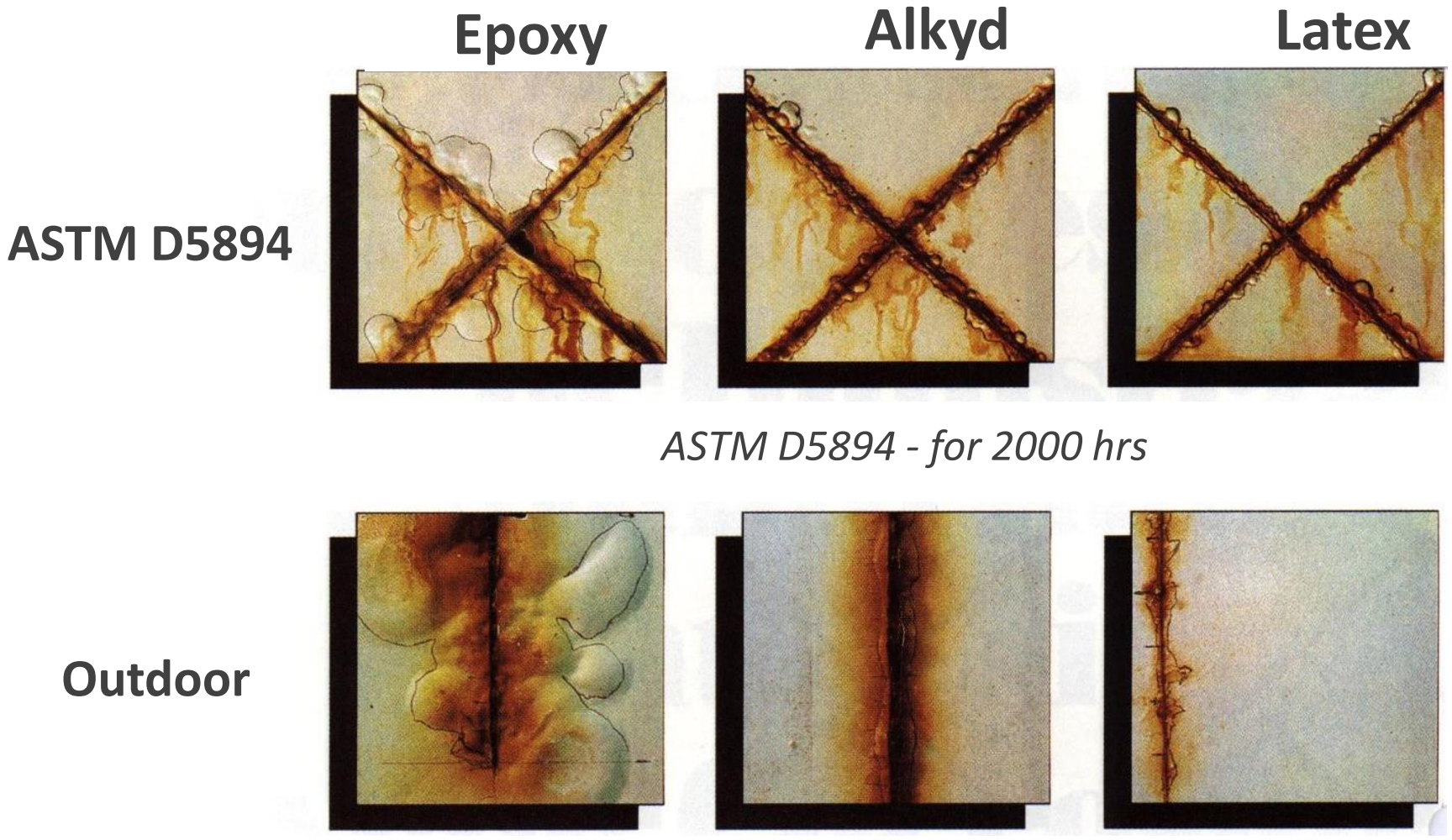
Cyclic Wet/Dry vs Outdoors

	Epoxy	Alkyd	Latex
Prohesion (ASTM G85 A5)			
Outdoor			

Salt Spray for 2000 hours (1000 for latex)

27 months outdoor marine environment

Combined Corrosion/Weathering vs Outdoors



ASTM D5894 - for 2000 hrs

27 months outdoor marine environment

Corrosion/Weathering Validation

- **Society for Protective Coatings (SSPC)**
- Cleveland Society for Coatings Technology (CSCT)
- American Association of State Highway and Transportation Officials (AASHTO)

SSPC

- Society for Protective Coatings
- 15 different systems
- Outdoor vs. accelerated
  - 31 months
- Accelerated tests
  - Salt spray 5%
  - Prohesion
  - 2 types of cyclic immersion tests
  - Combined corrosion/ weathering test

SSPC Test Results

Laboratory Test Method	Correlation w/Severe Marine Environment
Conventional Salt Spray	-0.11
Prohesion	0.07
Cyclic Immersion Procedures	0.48
Cyclic Immersion with UV Procedure	0.61
Combined Corrosion/ Weathering Cycle	0.71

Results stated are Spearman rank coefficient 1.0 = perfect correlation, 0 = random, -1 = perfect rank reversal

Topics

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- **Overview of current methods**
- Recent Studies
- Reproducibility challenges

ASTM D5894

7 Days

UVA-340	*4:00*	*0.89 W/m²/nm*	*60°C*
Condensation	*4:00*		*50°C*

7 Days, ASTM G85 A5

Fog (dilute solution)	*1:00*	*24°C*
Dry-off	*1:00*	*35°C*

ASTM D5894 Variations

- NACE TM0304, TM0404
  - Replaces dilute NaCl/$(NH_4)_2SO_4$ solution with ASTM D1141 synthetic seawater
- Freeze cycling added to US Federal Highway Administration test

Synthetic Sea Water (ASTM D1141)

Compound	Concentration (g/L)
$NaCl$ (sodium chloride)	24.53
$MgCl_2$ (magnesium chloride)	5.20
Na_2SO_4 (sodium sulfate)	4.09
$CaCl_2$ (calcium chloride)	1.16
KCl (potassium chloride)	0.695
$NaHCO_3$ (sodium bicarbonate)	0.201
KBr (potassium bromide)	0.101
All Others	<0.10

pH of synthetic seawater is 8.2

ISO 12944-6:2018

"Corrosion of steel structures by protective coating systems"

- Corrosivity categories described in ISO 12944-2 (based on ISO 9223)
- Durability classes described in ISO 12944-1
- ISO 12944-9 covers "off-shore" structures CX corrosivity classification (replaces ISO 20340)

ISO 12944-6

Annex B Cyclic Ageing Test

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
UV/condensation — ISO 16474-3			Neutral salt spray — ISO 9227			Low-temp. exposure at (−20 ± 2) °C

Repeat for 72 hours:
4 hours UVA-340, 0.83 W/m^2/nm at 340 nm, 60°C
4 hours dark condensation, 50°C

72 hours of continuous salt fog at 35°C

Rinse panels and put in a freezer for 24 hours

Which Weathering/Corrosion Test is the Best?

- Actually, all generally exhibit good correlation to field studies
- Test severities are similar at equal duration

Topics

- Accelerated tests for product qualification
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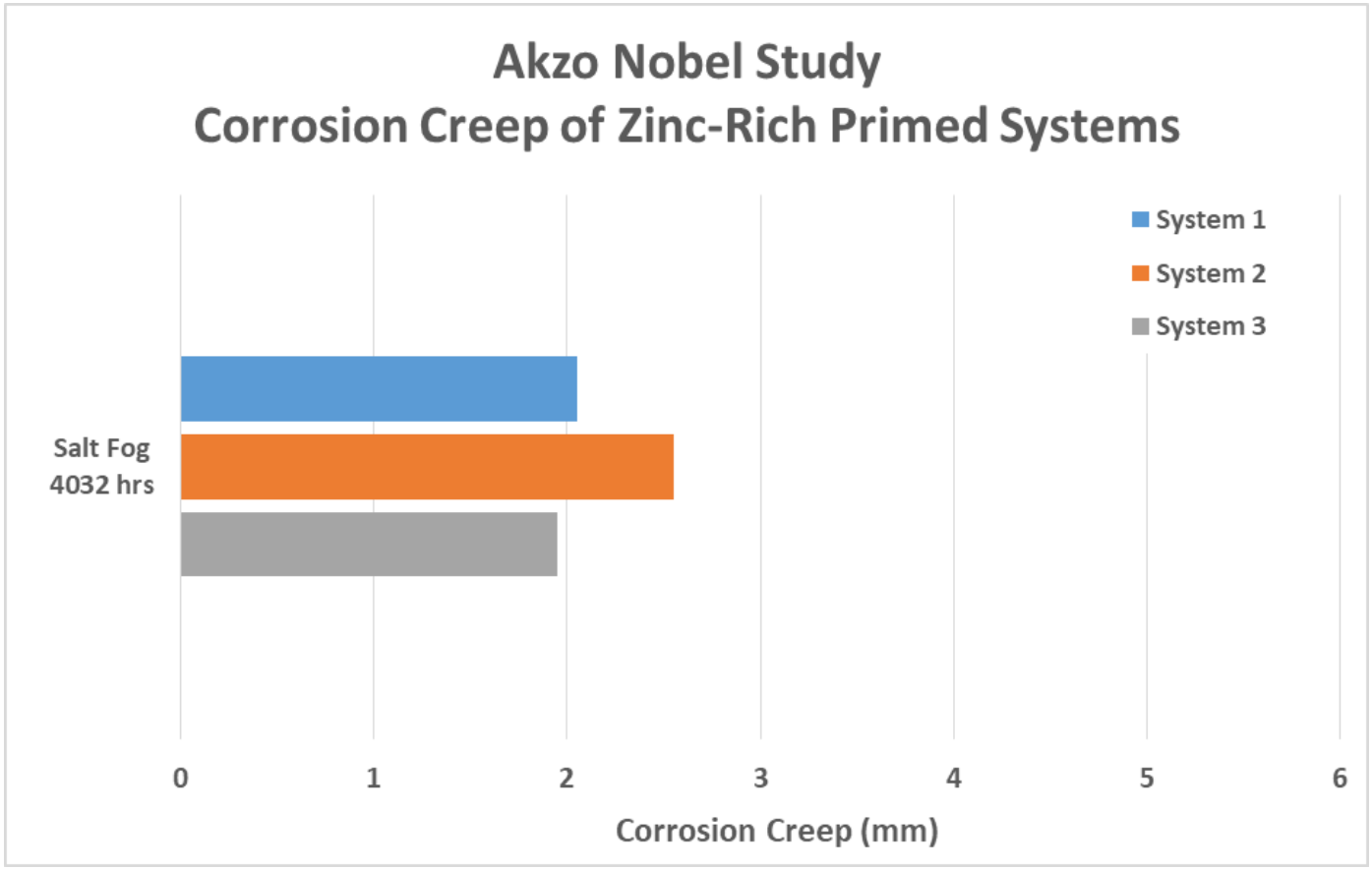
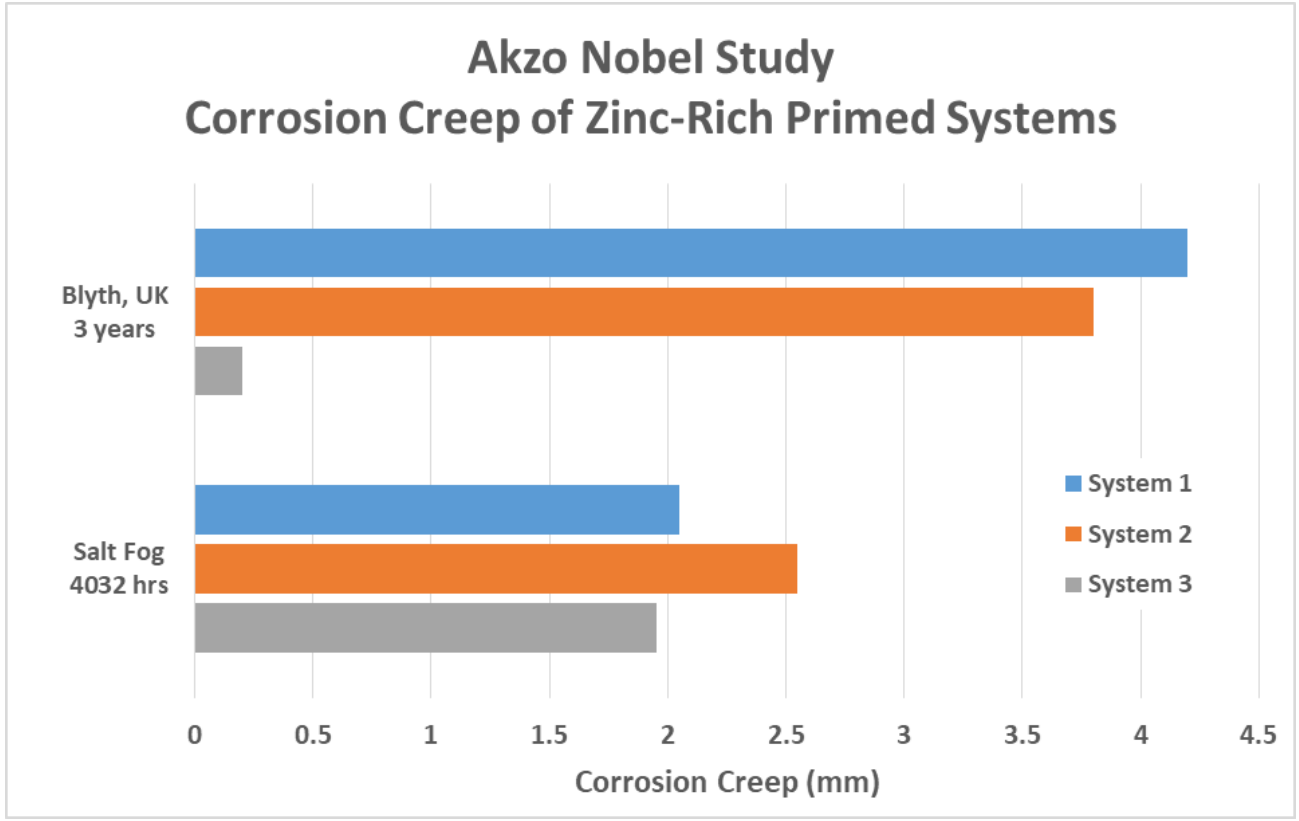
- Overview of current methods
- **Recent Studies**
- Reproducibility challenges

Correlation Study (Akzo Nobel)

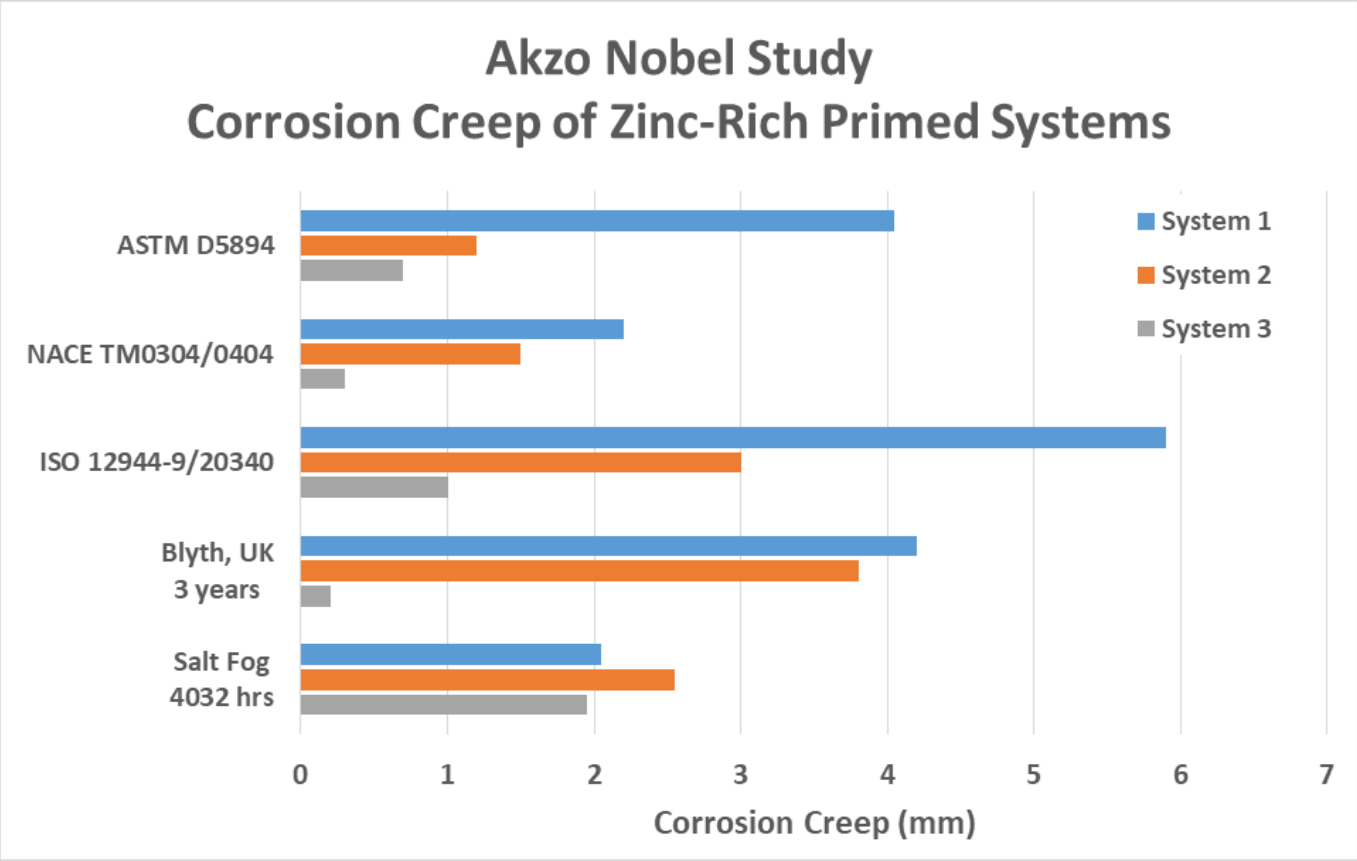


Three systems perform similarly to continuous salt fog

Salt Fog versus Outdoor Coastal Exposure



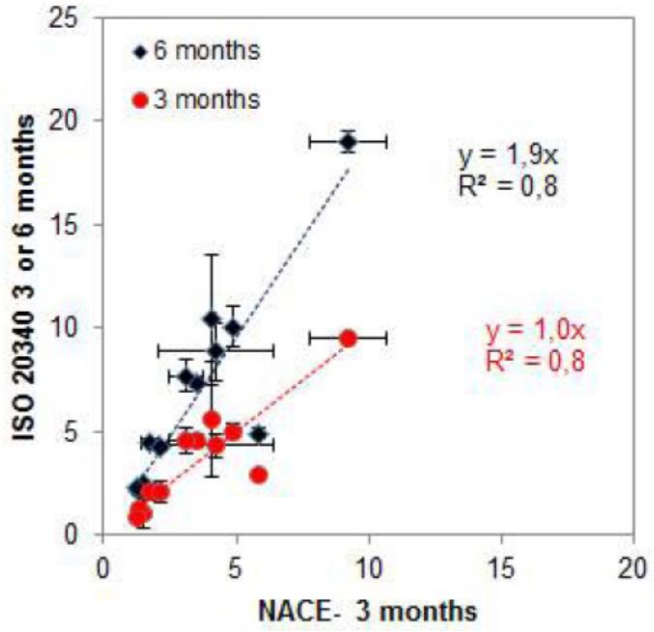
Combined Weathering/Corrosion Cycles



ISO 20340/12944-9 vs NACE TM0304

	Acceptable		Excluded	
ISO 20340 6 months	Zn primer	Other	Zn primer	Other
	≤3 mm	≤8 mm	>3 mm	>8 mm
Scribe 2,0mm	S1 S2	S6 S9 S12	S3 S4 S5	S7 S8 S10 S11
NACE rust creepage 3 months	Zn primer	Other	Zn primer	Other
	<1,5 mm	<3,5 mm	>1,5 mm	>3,5 mm
Scribe 2,0 mm	S1 S2	S6 S12	S3 S4 S5	S7 S8 S9 S10 S11

12 Coating systems on grit blasted steel panels
Pass/fail agreement on 11 of the 12 systems



ISO 20340/12944-9 and NACE methods have equal severity on a time scale

Nathalie LeBozec and Cecile Hall, French Corrosion Institute; Denis Melot, Total
NACE Corrosion 2014 Paper 3762

Reproducibility Concerns

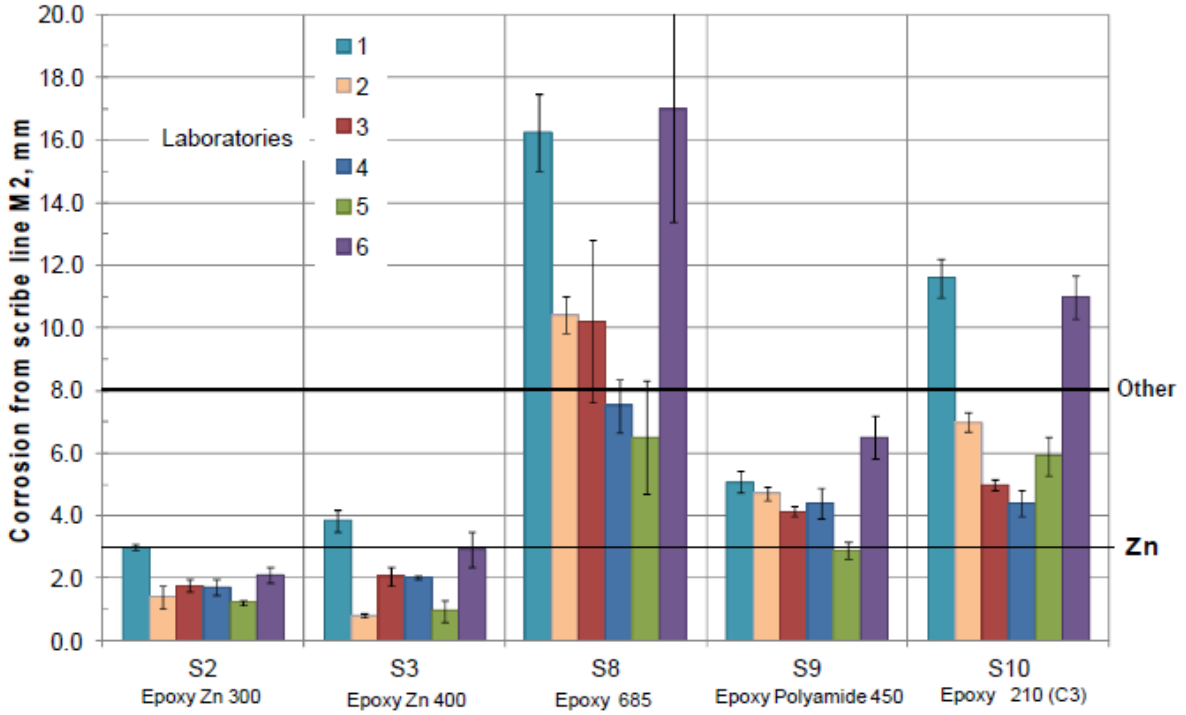


Figure 2 : Corrosion extent from the scribe line after ISO 20340 Annex A test. Requirements for Zn Primer (<3mm) and non-Zn primer (<8mm) are highlighted.

- *For 2 of 5 coating systems, all six labs agreed on pass/fail result*
- *2 of 5 systems had multiple contradictory pass/fail results*

Nathalie LeBozec, French Corrosion Institute; Laurence Bougon, CEREMA; John Carter, EXOVA; Tanja Scholz, Fraunhofer IFAM; Ole Oystien Knudsen, SINTEF; Adeline Flogard, SP Technical Research Institute of Sweden

NACE Corrosion 2016 Paper 6991

Topics

- Accelerated tests for product qualification
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- Overview of current methods
- Recent Studies
- **Reproducibility challenges**

Reproducibility Case Study – Prohesion

- ASTM G85 Annex 5 (Prohesion)
- Part of ASTM D5894, modified in NACE standards

ASTM G85 Annex 5 (Prohesion)

1 Hour fog at “ambient” temperature (room should be 24°C)
1 hour dry-off 35°C

Solution: 0.05% NaCl
0.35% $(NH_4)_2SO_4$
pH: 5.0 - 5.4

ASTM G85 Annex 5 (Prohesion)

- How dry is dry?
- How long does it take to achieve a “dry” condition?

Answers are in the non-mandatory appendix: “within ¾ hour all visible moisture is dried off the specimens”

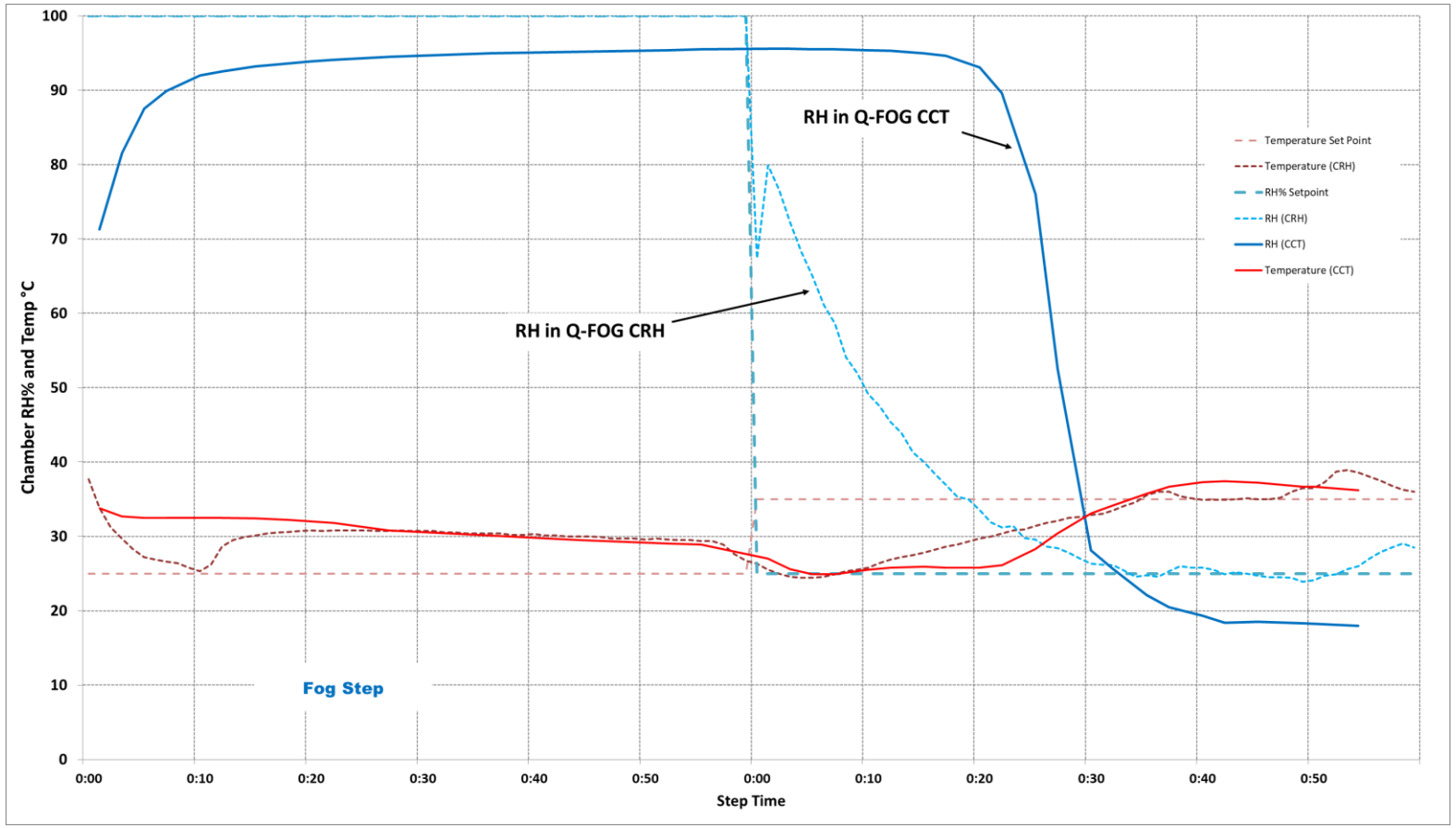
Problem Statement

My new chamber isn't as severe as my old one

After 1000 hours of Prohesion, new chamber produced less severe results on a coatings test

Q-FOG CCT *Q-FOG CRH*

Prohesion RH Profile in Two Chambers



Q-FOG CCT Cycle:

Step 1: Fog 24°C 1:00

Step 2: Dry 35°C 1:00

Step 3: Go to Step 1

Q-FOG CRH Cycle:

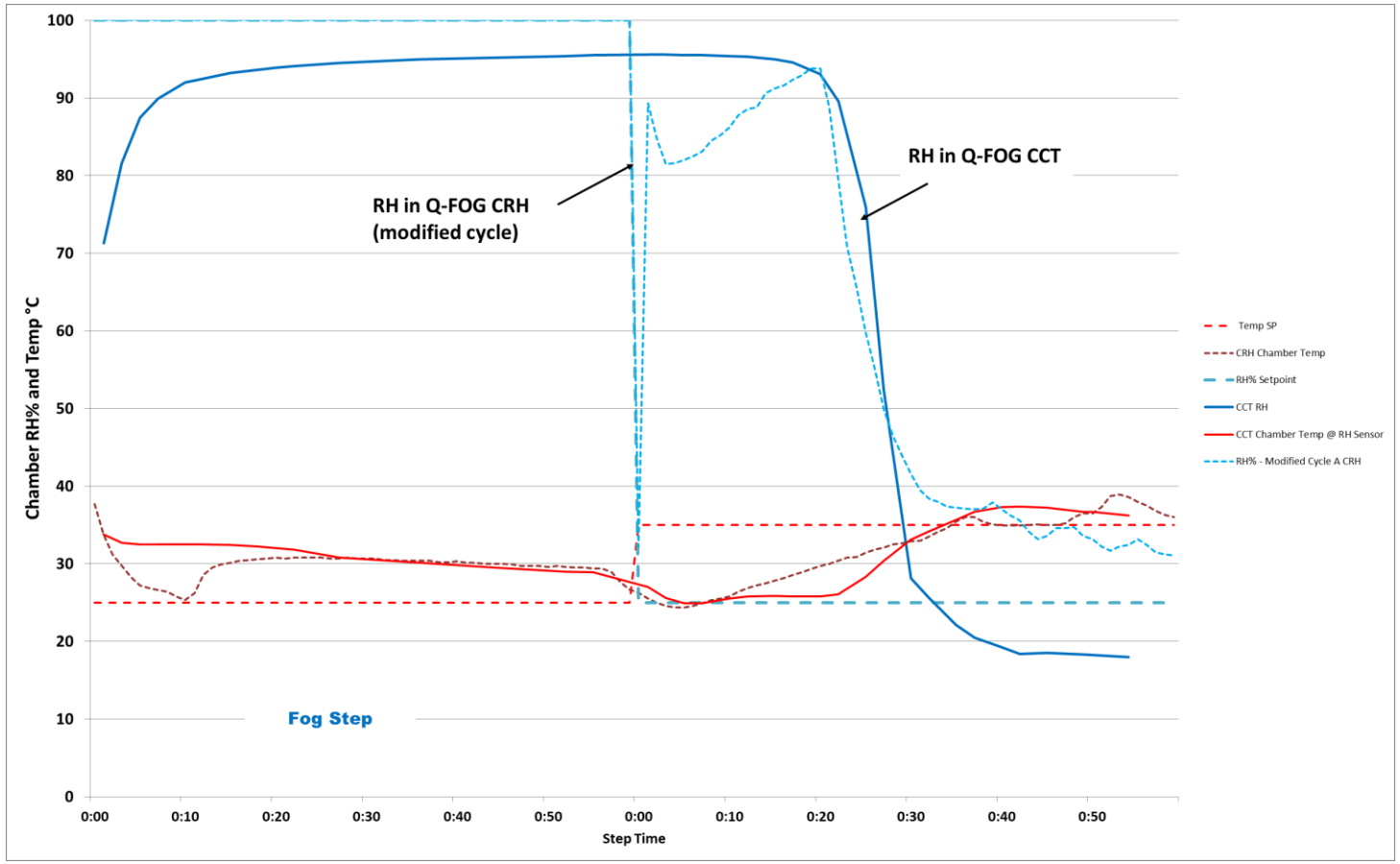
Step 1: Fog 24°C 1:00

Step 2: RH 35°C, 25% RH 1:00

Auto transition

Step 3: Go to Step 1

Modified CRH Prohesion Cycle



Modified Prohesion Cycle:

Step 1: FOG 24°C 1:00

Step 2: RH 35°C, 95%RH 0:30

Auto transition

Step 3: RH 35°C, 25% RH 0:30

Auto transition

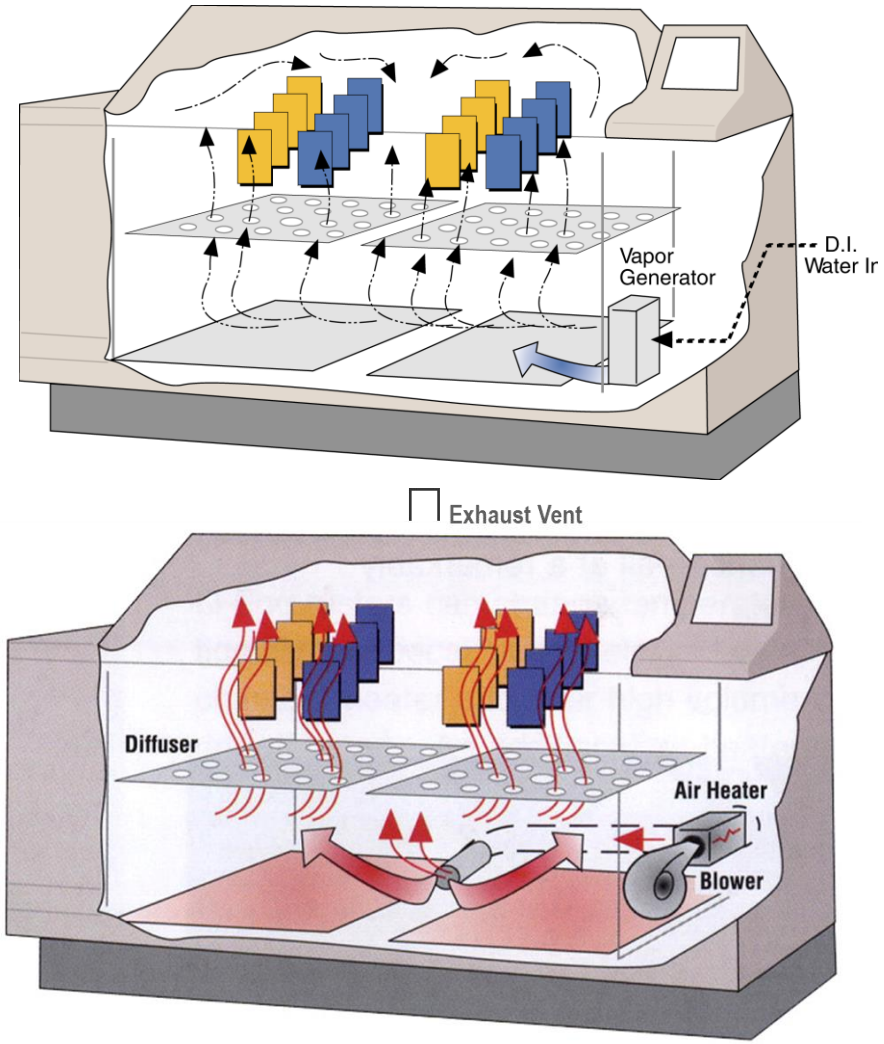
Step 4: Go to Step 1

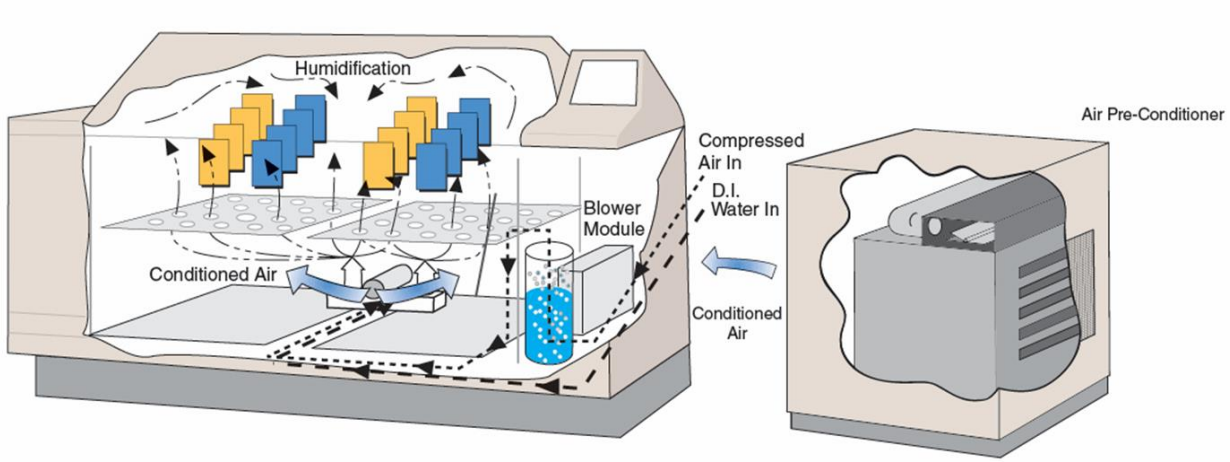
Q-FOG CCT

Q-FOG CRH (modified cycle)

Q-FOG CCT vs CRH

Q-FOG CCT has simple humidity generation without air flow and dry-off by blown heated air through chamber

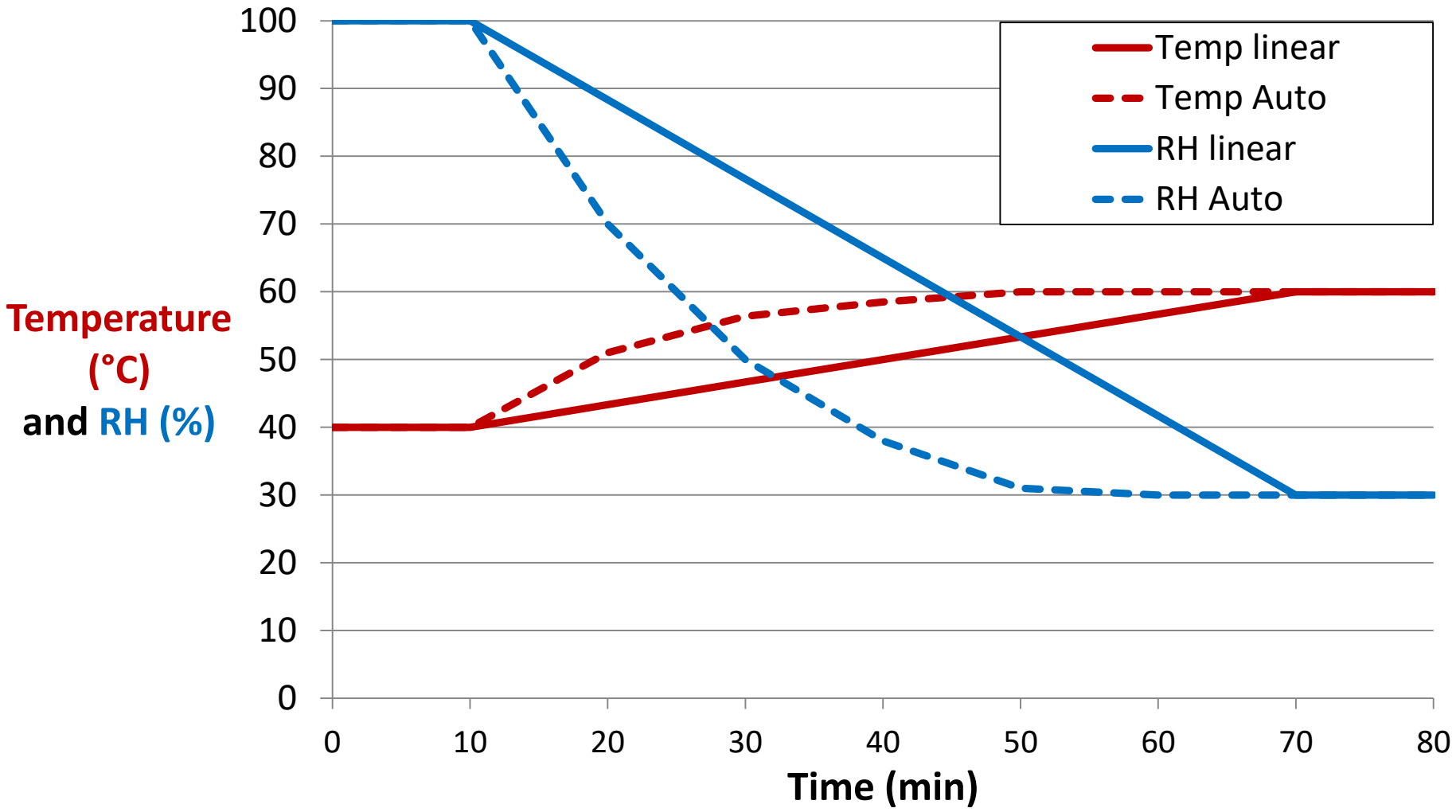




Q-FOG CRH has atomizing humidification nozzles, an air drier (chiller), and a recirculation system with damper to regulate moist and dry air streams

Q-FOG CRH Linear and Auto Ramping

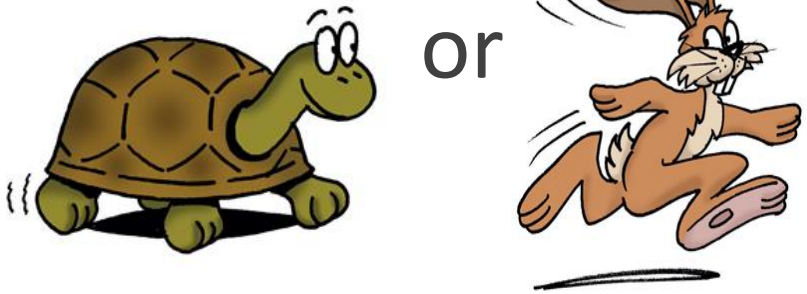
Transition from Wet to Dry



Improving Test Reproducibility

- Specify chamber RH and transition times of corrosion cycles
- Develop specimen handling instructions that reduce variability (lab conditions during handling, maximum time outside the chamber, whether rinsing should be performed)

Which technician runs the test?



Thank you

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A more in-depth presentation on this topic will be presented 24-September at 8a.m. and noon Eastern Daylight Time